Design of Safety Drive Control Unit for AC Signal without Relay Contact

Shuai Han
Beijing National Railway Research & Design Institute of Signal & Communication Group Co., Ltd., Beijing, China, Email: hanshuai@crscd.com.cn

Huan Ding
Beijing National Railway Research & Design Institute of Signal & Communication Group Co., Ltd., Beijing, China, Email: dinghuan@crscd.com.cn

Pengfei Dai
Beijing National Railway Research & Design Institute of Signal & Communication Group Co., Ltd., Beijing, China, Email: daipf @crscd.com.cn

Yiping Xiao
Beijing National Railway Research & Design Institute of Signal & Communication Group Co., Ltd., Beijing, China, Email: xiaoyiping@crscd.com.cn

Shumin Ge
Beijing National Railway Research & Design Institute of Signal & Communication Group Co., Ltd., Beijing, China, Email: gaishumin@crscd.com.cn

Xiguo Ren
Beijing National Railway Research & Design Institute of Signal & Communication Group Co., Ltd., Beijing, China, Email: renxiguo@crscd.com.cn

ABSTRACT

Aiming at the deficiencies of the existing AC signal control system with relay interlocking, this paper introduces a safe driving control unit of AC signal without relay contact. Based on the principle of distributed control and the working principle of dual CPU, it could realize distributed control trackside signal of the interlock-zone and stations and safe drive signal. And, it uses the high frequency and high voltage characteristics of power electronic devices to realize the miniaturization and full-electronic control of the signal control system. At the same time, the control unit solves the problems of current surge when the relay is started, complex control circuit and high maintenance cost. Experiments show that the unit runs stably and has strong practicability. It will play an important role in the distributed trackside control system.

CCS CONCEPTS

• **Hardware**; • **Hardware validation**; • **Physical verification**;

KEYWORDS

AC-signal safety control, Distributed control, All-electronic

ACM Reference Format:

Shuai Han, Huan Ding, Pengfei Dai, Yiping Xiao, Shumin Ge, and Xiguo Ren. 2021. Design of Safety Drive Control Unit for AC Signal without Relay Contact. In *The 5th International Conference on Computer Science and Application Engineering (CSAE 2021), October 19–21, 2021, Sanya, China.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3487075.3487179

CSAE 2021, October 19–21, 2021, Sanya, China

ACM ISBN 978-1-4503-8985-3/21/10…$15.00
https://doi.org/10.1145/3487075.3487179

1 INTRODUCTION

As the basic equipment for commanding the driving and shunting operations, the semaphore is a key factor to ensure the safety of railway transportation and improve the efficiency of transportation. At present, Chinese signal machine basically uses AC 220V power supply to directly supply power. The signal machine's drive control is realized through the step-down of the transformer with the signal machine itself, and the safety of the signal machine's drive is improved by using the relay's fault asymmetry [1-7]. At the same time, the signal cable connection is used to realize the physical connection between the signal machine and the control system, and the data communication and command control between indoor signal equipment and trackside equipment are realized through centralized control. Due to the complex circuit control of the existing signal machine, the large impulse current of the relay, and the large space occupation, with the continuous advancement of science and technology, 5G network technology, optical fiber communication and other communication technologies are adopted to install miniaturization and intelligentization on the trackside. Signal safety control equipment to realize the integrated distributed interlocking control of interlock-zone and platform is bound to be the development direction of signal control system [2] [5].

2 SYSTEM INTRODUCTION

The safety drive control unit of AC signal without relay contact (abbreviated as: signal control unit) is based on the theory of distributed control to realize distributed control of AC signal [2] [5]. Its control architecture is shown in Figure 1. The central control equipment in each station/interlock-zone is physically connected to the signal control unit through optical fiber or Ethernet. First of all, the central control equipment sends the control commands of the signal to the trackside equipment through comprehensive logic operations according to the train's operating conditions and track status information; Then, the signal control unit realizes the safety control of the signal and the light position display according to the parsed control command; Finally, the signal control unit completes the status detection of the signal display, and returns the

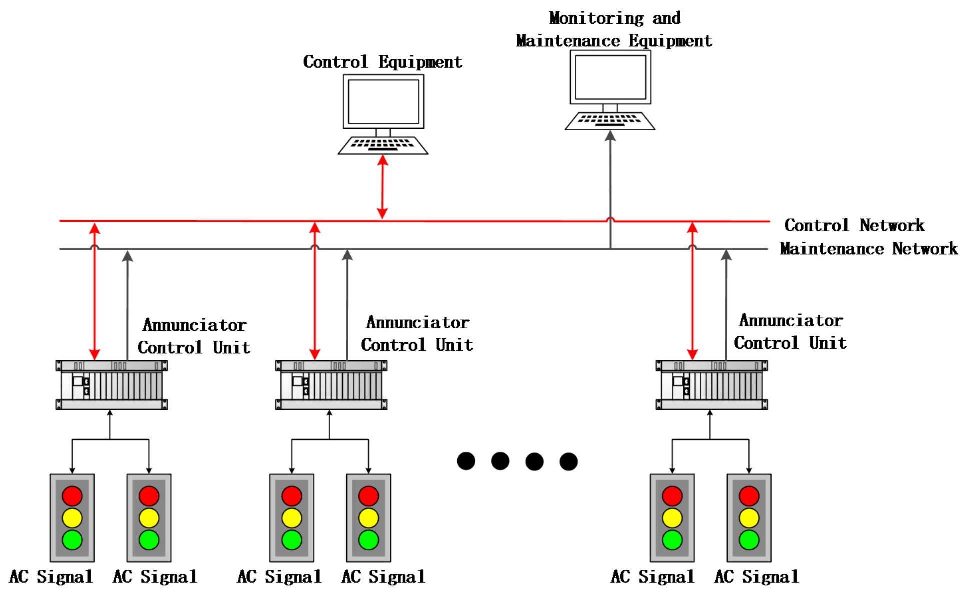

Figure 1: Field Application Diagram.

Table 1: Feature Comparison Table

	Signal control unit	Existing signal control system
Control architecture	Distributed control, Centralized control	Centralized control
Circuit design	All-electronic circuit	Circuit with relay
Drive and collection method	Real-time collection, Hardware heterogeneity	Circuit with relay
Reliability	Single point of failure does not affect the whole	Single point of failure affects the whole
Safety	At the time of failure, it actively turn off the output	At the time of failure, it passively turn off the output
Failure response time	Fast	Slow
Maintainability	Easy	Difficult

status information to the monitoring and maintenance equipment of the station/interlock-zone. To ensure the safety and availability of the signal control unit, the system adopts "Double Two out of Two" redundant architecture design, through the time and task synchronization of the dual CPU, only when the output data is relatively consistent can the control of the external device be realized, thereby improving the safety and reliability of the system; through two sets of redundant devices to achieve functional hot-backup, thereby enhancing the availability and effectiveness of the system. At the same time, by adding monitoring methods such as network communication, signal status, output data, etc., so that any point in the link can prompt faults in time, and finally achieve the goal of safe control of trackside AC signals.

The signal control unit could realize the safety control and real-time monitoring of the trackside signal, it supports the decentralized and intelligent management of field equipment. It has the advantages of clear layering, easy expansion, simple connection, and it is compared with the characteristics of the existing signal control system in the table 1 [2][4] [6].

3 HARDWARE DESIGN

The signal control unit is used as the execution unit of the interlocking system to realize the interlocking function; its performance is directly related to driving safety. Compared with the existing semaphore control system which uses a more complicated circuit with relay to realize the drive control of the signal [3] [4]. This design uses power electronic devices to achieve full electronic control; it adopts the dual CPU "two out of two" method to compare input and output data to reduce system failure due to single-point failures, and ultimately realize the safety and reliability of the signal control unit. The hardware design structure is shown in Figure 2, which is mainly composed of five parts: logic control module (A and B), safety drive control module, acquisition and monitoring module (A and B), power supply module and external communication module.

3.1 Logic Control Module

As the core part of the signal control unit. When controlling the signal, two independent CPUs not only compare the central control commands obtained by the communication interface module.

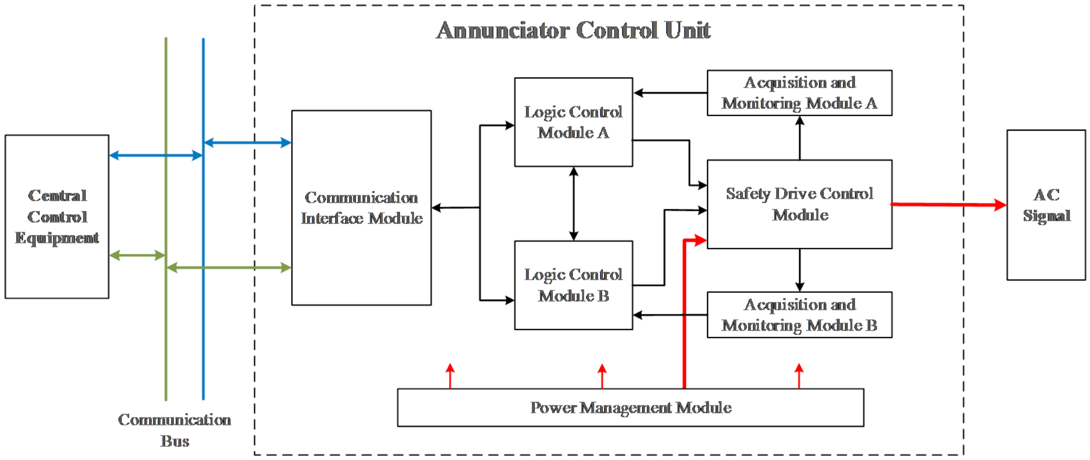

Figure 2: Hardware Structure Design Drawing.

Moreover, the consistency judgment of the status monitoring information of the signal provided by the collection monitoring module is carried out, and feedback the comparison result to the control center. When any logic module detects a failure, due to the consistency comparison failure, the signal control unit will lead to failure-safe processing and no drive output. At the same time, when the drive power is converted, the two logic control modules will generate pulse signals of different frequencies and control signals which based on the collected data of the monitoring module to control the drive electrical conversion in the safety drive control. Through the output voltage Real-time monitoring with current to realize the safety control of the AC signal.

3.2 Safety Drive Control Module

As the safety driving part of the signal control unit. This module mainly realizes voltage conversion and safety driving functions. The hardware mechanism design is shown in Figure 3

1) Voltage conversion: First of all, the module uses filtering and rectification circuits to complete AC-signal conditioning. Then the AC signal is converted into a high-frequency pulse signal through a high-frequency voltage conversion circuit. Finally, it converts the high-frequency pulse signal into the driving power required by the signal.

2) Safety drive: On the one hand, two different frequency pulse signals sent by the logic control module are used to generate the working power of the electronic components used to drive the conversion circuit through the internal safety and circuit; On the other hand, the drive signal is controlled by the drive control signal sent by the logic control module to control the drive electric conversion; When an abnormal fault occurs, the chip driving voltage converted by "safety AND-gate " and the control signal jointly complete the safety driving control of the annunciator.

3.3 Acquisition and Monitoring Module

As the monitoring part of the "health" status of the signal machine control unit. This module mainly undertakes the task of driven

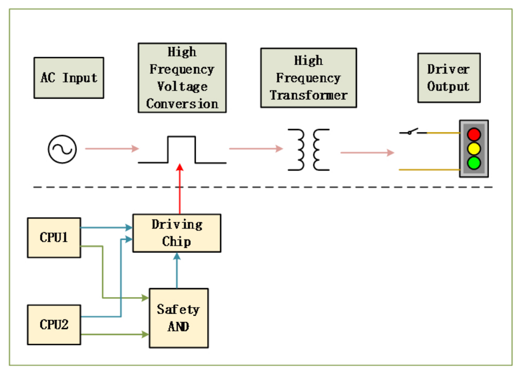

Figure 3: Hardware Structure Design of Safety Drive Control Module.

acquisition monitoring and periodic self-checking of the equipment. The hardware mechanism design is shown in Figure 4

1) Acquisition and monitoring: As shown in the figure. On the one hand, it uses the hardware heterogeneous method to improve the accuracy and effectiveness of the collected data; on the other hand, it uses "Two out of Two" method to improve the safety and reliability.

2) Periodic self-checking: In order to ensure the availability and safety of the signal control unit, it uses the principle of "cold wire detection" to do periodic self-checking for the drive circuit [4] [6]. The circuit design is shown in Figure 5. In the figure, U_i is the voltage of the first conversion, and it is converted to different driving voltage U_o according to different signal types; K1 and K2 are electronic switches; R1 and R2 are detection resistors; and L1 is a signal. Firstly, when the signal control unit is working normally, the logic control module drives the K1 and K2 to light up the signal. Then, the acquisition and monitoring module monitors the change of the output signal by collecting the current flowing through R2. Finally, the logic control module completes dynamic output adjustment and fault alarms based on the collected data. In order to complete the self-checking of the signal, on the one hand,

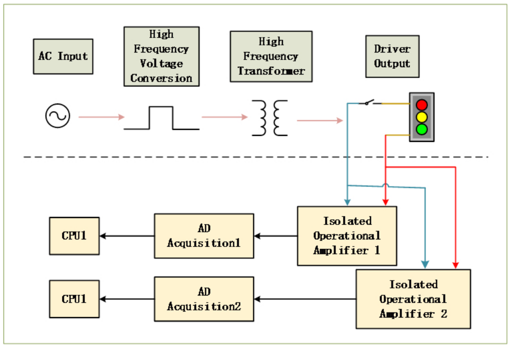

Figure 4: Hardware Design of Acquisition and Monitoring Module.

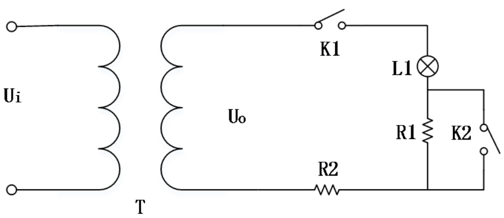

Figure 5: Hardware Design of Self-Checking Circuit.

the logic control module turns on K1 and turns off K2; On the other hand, by adjusting the resistance of the resistor R1, the current passing through L1 is not enough to light the signal.

4 SOFTWARE DESIGN

The software of the signal control unit mainly completes the safe communication with the control center and the signal machine, the task analysis of the center and the command translation of the signal, and monitors the working status of the signal and itself. At the same time, the " Two out of Two " structure is adopted to realize the task and time synchronization of the dual CPU, and the safety control of the signal is realized by comparing the input and output data [2-5]. The flow chart of software control status is shown in in Figure 6

After the signal control unit is started, the software first enters the initialization state. It completes the work of driver initialization, configuration reading, and startup self-checking in this state. Then, the software enters the cycle state. When the unit does not receive the command from the equipment in the control center, it performs self-checking periodically in order to complete the monitoring of its own "health"; When the unit receives the lighting command of signal issued by the control center, it needs to complete the effective judgment of the command by collecting the status of the signal. If the command is invalid, the current state is maintained and the state is fed back to the center. If the command is valid, it enters the drive control start state and the drive output state. In the start state of the drive control, the software changes the duty cycle of the PWM wave at startup to realize the "soft start" of the drive. Compared with existing products, this method could reduce the

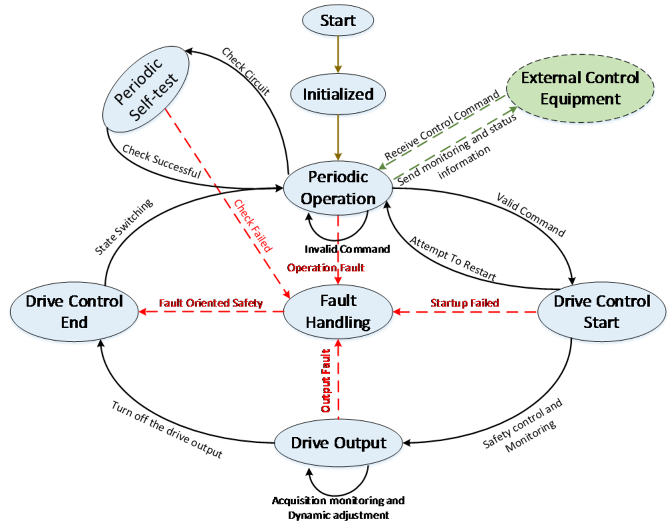

Figure 6: Flow Chart of Software Control State Transition.

instantaneous current when the unit is starting, thereby reducing the harm of the control system to the signal [3] [4]. At the same time, dual CPU jointly complete the safe conversion, control and monitoring of the drive voltage. In the drive output state, the unit needs to collect the output voltage and current. At the same time, the dual CPU jointly complete the safety monitoring and dynamic adjustment of the drive output.

5 EXPERIMENTAL VERIFICATION

In order to verify the usability and accuracy of the principle design of the system, the function verification and performance evaluation of the signal control unit are completed through the interlocking environment. The experimental environment is shown in Figure 7

When the central control equipment issues an interlock command, the unit first completes the command analysis and drive control, and finally lights up the corresponding lamp position according to the drive signal. The display effect is shown in Figure 8. (In the drive output waveform, the yellow waveform represents the operating current of the signal, about 1A; the blue waveform represents the working voltage of the signal machine, about 220VAC).

6 CONCLUSION

As the basic equipment for commanding traffic and shunting operations, its performance directly affects the efficiency of vehicle traffic, and even affects the safety of railroad transportation and passenger life. This design uses the high frequency and high withstand voltage characteristics of power electronic devices to eliminate the relays of the existing signal machine drive control part to realize the drive output and control of the signal. It uses methods such as dual CPU comparison, the same drive and the same acquisition, and hardware heterogeneity to improve the safety and reliability of the control system. In order to improve the utilization rate of the signal machine control system and reduce the failure rate of the signal machine, it uses "cold wire detection technology" to realize

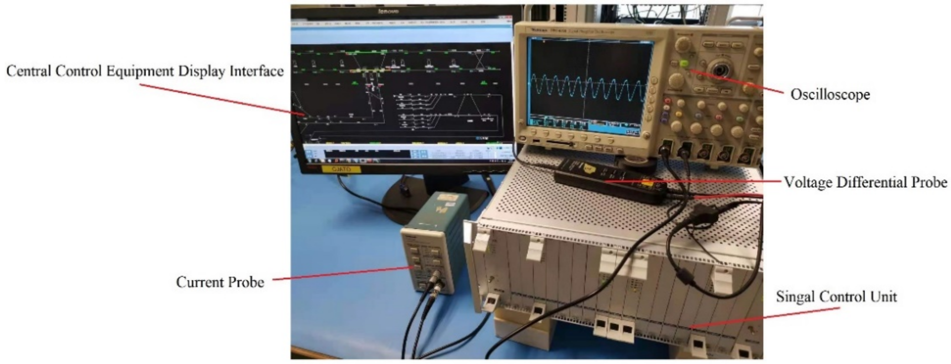

Figure 7: Test Environment.

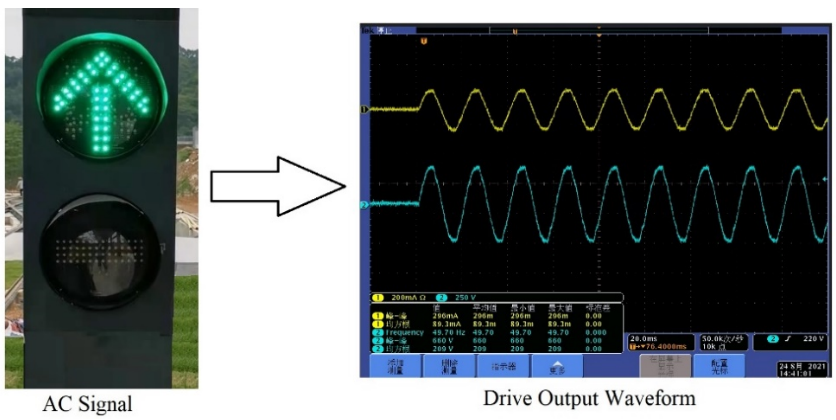

Figure 8: Signal Display and Drive Waveform.

equipment self-checking. In the end, the feasibility scheme demonstration was completed through experimental verification, and the research has high practical value and reference value in the future trackside integrated control system.

REFERENCES

[1] Limin Fu (2020). Research on Development and Application of Full Electronic Interlocking [J]. Railway Signalling & Communication Engineering, 3: 32-38
[2] YunFei Chi (2015). The Research on signal Machine based on distributed control architecture [D]. Chang'an University.
[3] Juan Liang, Shiru Qu (2008). Design on intelligent traffic machine driver board based on MCS-51 and CPLD [J]. Industrial Instrumentation & Automation, 1: 46-48.
[4] Rui Hu (2016). Design and Implementation of CTCS Ground Object Controller [D]. Beijing Jiaotong University.
[5] Jianqiang Liu (2015). The research of automatic block interval distributed signal control unit [D]. Lanzhou Jiaotong University.
[6] Jin Jin, Jinfeng Yang, Baofeng Zhang (2015). The main controller system design of shunting signal filament conversion [J]. Journal of Tianjin University of Technology, 31(5), 44-50.
[7] Jun Xiao, Yimin Mo, Xiaoguang Wang, Shuncheng Shen, Jinfang Xie (2000). A PLC Control System of Signal Lamps in Locomotive Maintenance Sections [J]. Journal of Wuhan University of Technology, 22(5), 27-30.